EMBEDDED OPEN SOURCE SUMMIT

EMBEDDED LINUX CONFERENCE

Quality Beyond KernelCI in Upstream Linux for TI SoCs

2024-04-18, Seattle

Barry Sheraw
Nishanth Menon
Minas Hambardzumyan

Texas Instruments

About us: TI Processors and Open source

Decades of contribution and collaboration

Ingrained culture to give back to the community

Upstream FIRST!

Focus on long term, sustainable and quality products

Upstream and opensource ecosystem in device architecture

Upstream FIRST mentality!

Introduction to the Speakers

Barry Sheraw, *Software Development Manager, Dallas, TX*

Barry joined TI's High Performance Analog EDA organization in 2006 as an EDA Software Engineer focusing on automation tools and is currently manager of the Linux System Test and Integration team. Barry received his Bachelor's degree in Mathematics/Computer Science from Carnegie Mellon University in 1996 and his Master of Computer Science from Rice University in 1998.

Nishanth Menon, *Senior Member Technical Staff, Texas Instruments*

Nishanth has been working with TI for over 18 years and is currently part of TI's Embedded Processing organization as a Linux/Systems architect working with Jacinto and Sitara Processor families. He is also a long time linux kernel contributor and currently active Linux kernel maintainer for TI's K3 device trees among other stuff he does.

Minas Hambardzumyan, *Software Developer, Dallas, TX*

Minas joined Texas Instruments Analog EDA organization in 2007, where he focused on development of design verification tools for ESD and ERC robustness. In 2021 Minas transitioned to the Embedded Processors organization, where he leads development of Linux system test tools and infrastructure. Minas holds a master’s degree in Physics from Yerevan State University.

Disclaimers

- This is a technology presentation, not product-readiness or roadmap commitment
- Opinions presented here are that of the speakers and may not reflect that of Texas Instruments Inc.

Overview

- Motivation and Background
- Upstream Testing
  - KernelCI Testing
  - Upstream CI/CD Testing
  - Full Upstream System Test
- Towards Common Testing…

Motivation

- Why use KernelCI?
  - Common platform to help kernel maintainers gauge Linux Kernel quality by publishing test results for TI platforms
  - Get notifications on upstream Linux Kernel regressions
  - Gain better confidence on results by testing images built externally

Test Infrastructure – TI's Global Test Farm

Upstream Testing

- KernelCI Testing
- Upstream CI/CD Testing
- Full Upstream System Test

Upstream Testing

- **KernelCI Testing**
- Upstream CI/CD Testing
- Full Upstream System Test

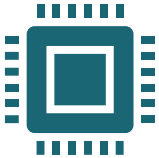
KernelCI Upstream Testing

- Automated build of test collateral
  - Boot images built locally
  - KernelCI build
    - Kernel files
    - dtb files
    - File systems (Debian and buildroot)
- Tests executed in local Test Farm on EVMs
- Results automatically uploaded to KernelCI storage to enable web-based review

KernelCI Testing Architecture

KernelCI

API Server



Storage Server

Web Dashboard

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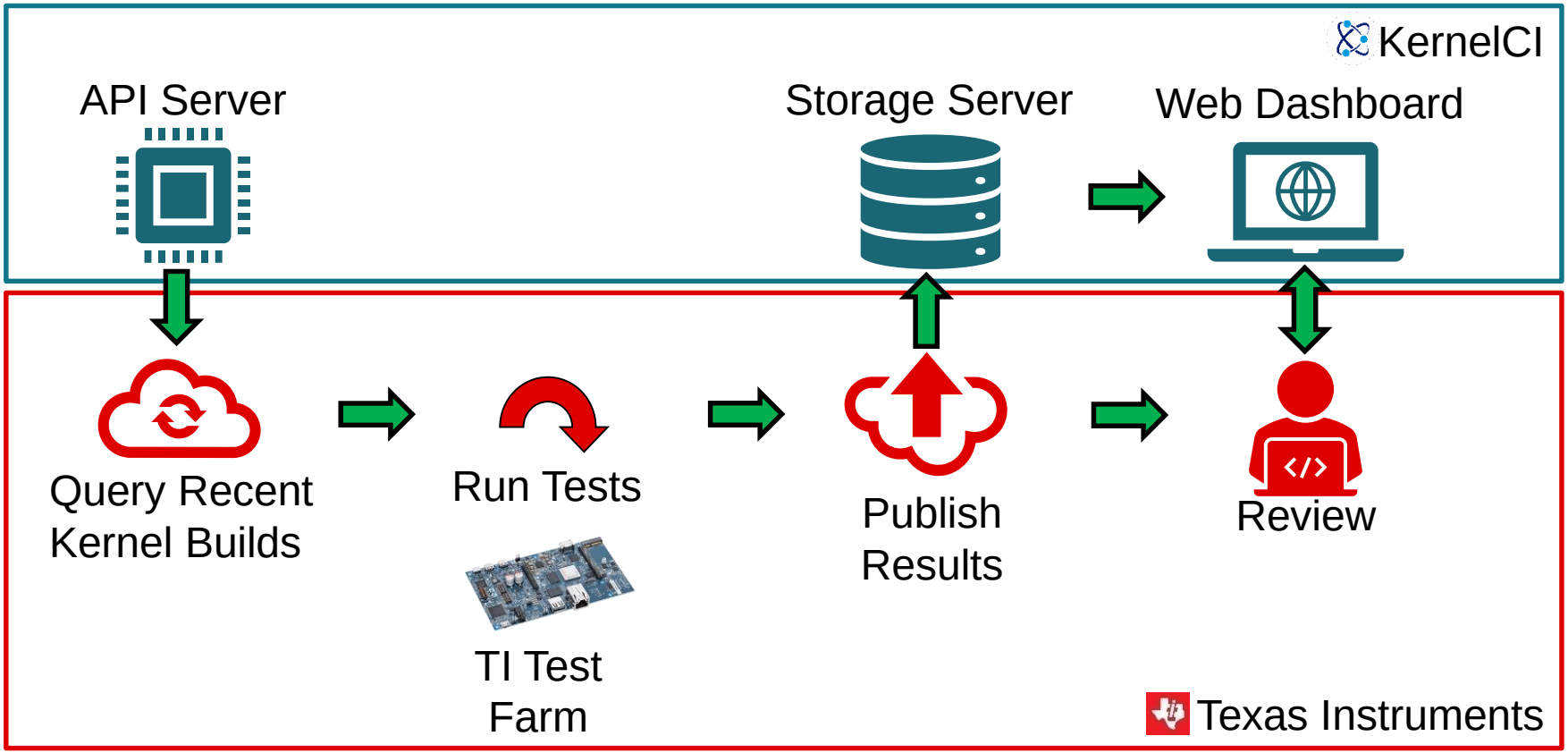
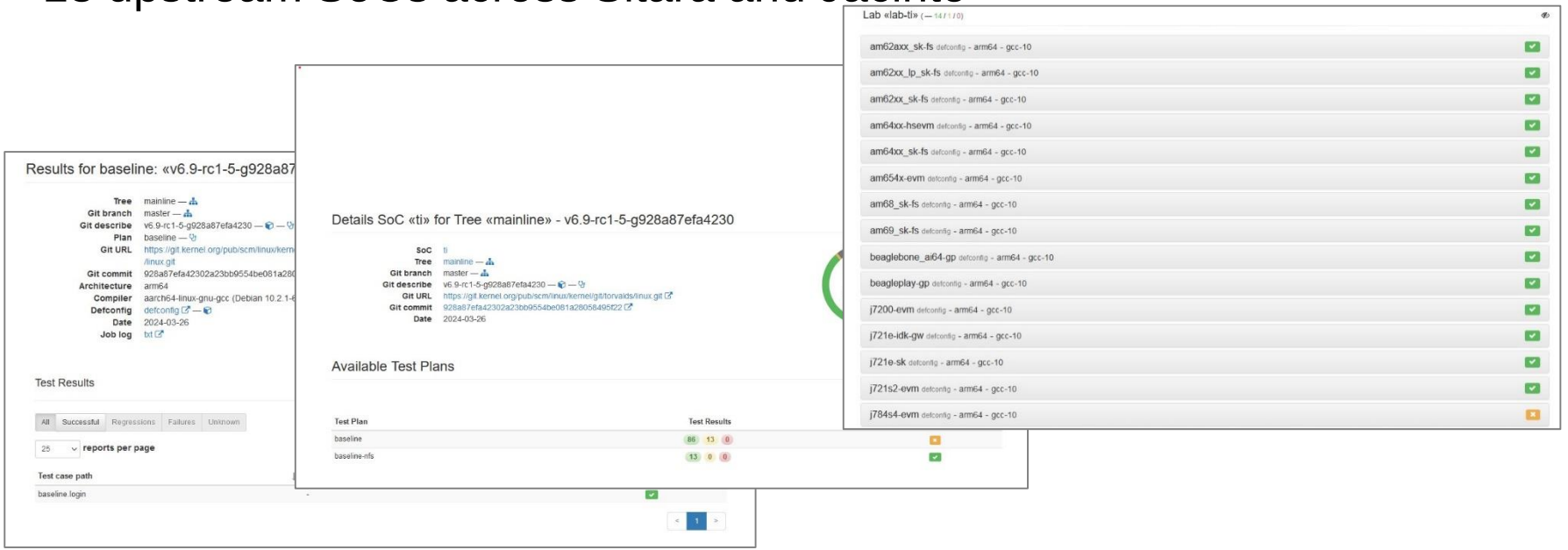
KernelCI Testing Architecture



KernelCI Testing Status

- Nightly boot tests – ltp and KSelfTest coming soon…
- 13 upstream SoCs across Sitara and Jacinto



Upstream Testing

- KernelCI Testing
- **Upstream CI/CD Testing**
- Full Upstream System Test

Upstream CI/CD

- End-to-end automation of latest upstream build, test and release
  - Builds automatically initiated
  - Test plans automatically executed on test boards and results tabulated
- Build collateral & test reports automatically released to customer facing portal

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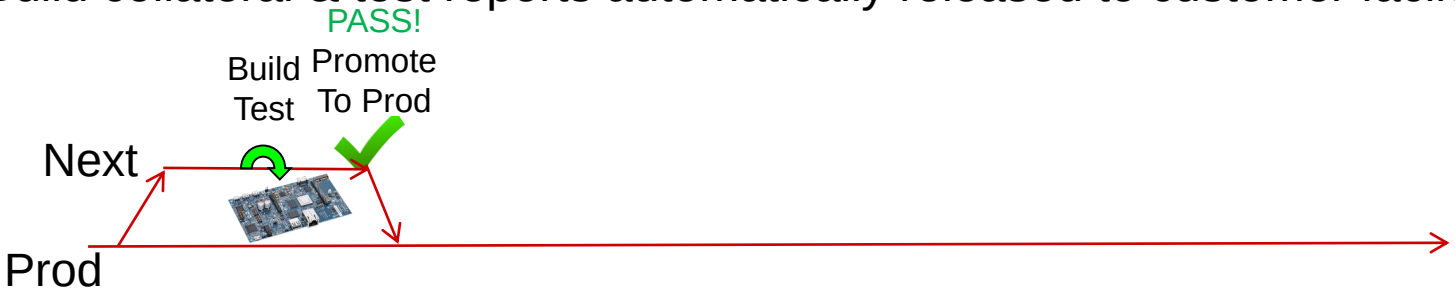

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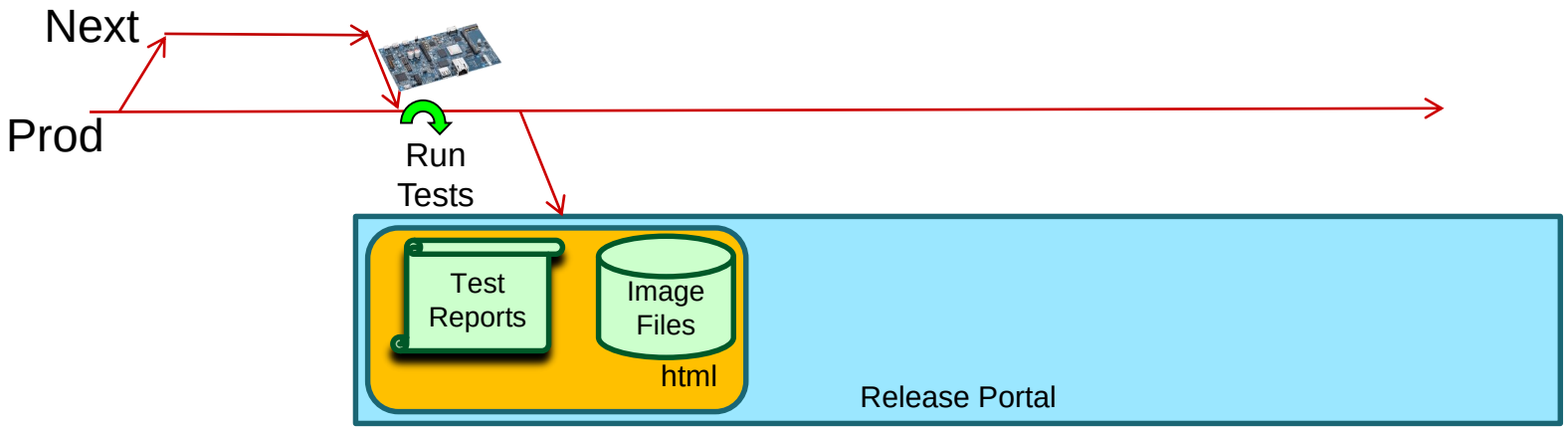

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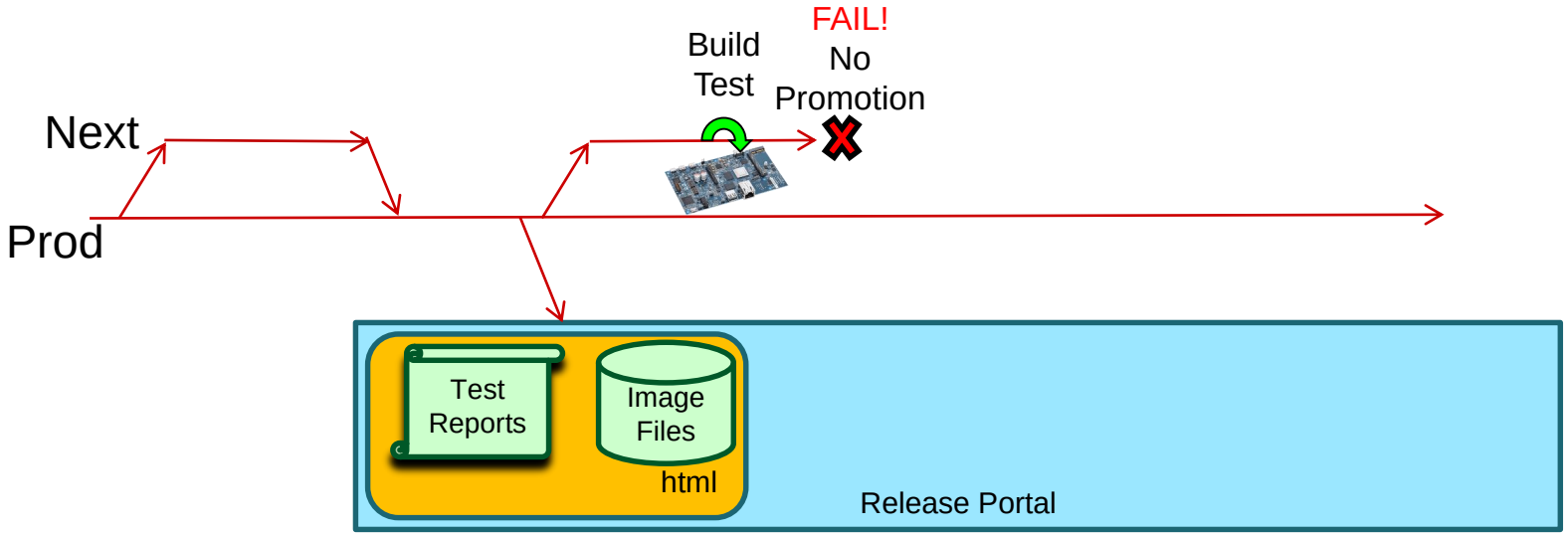

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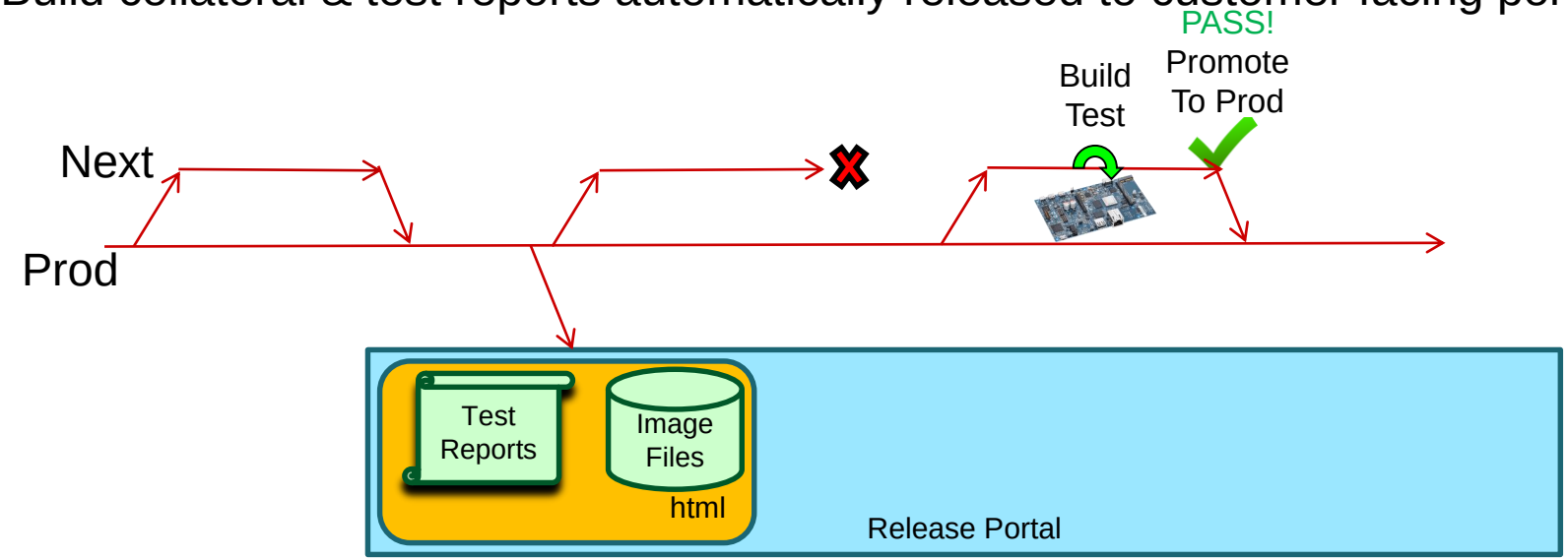

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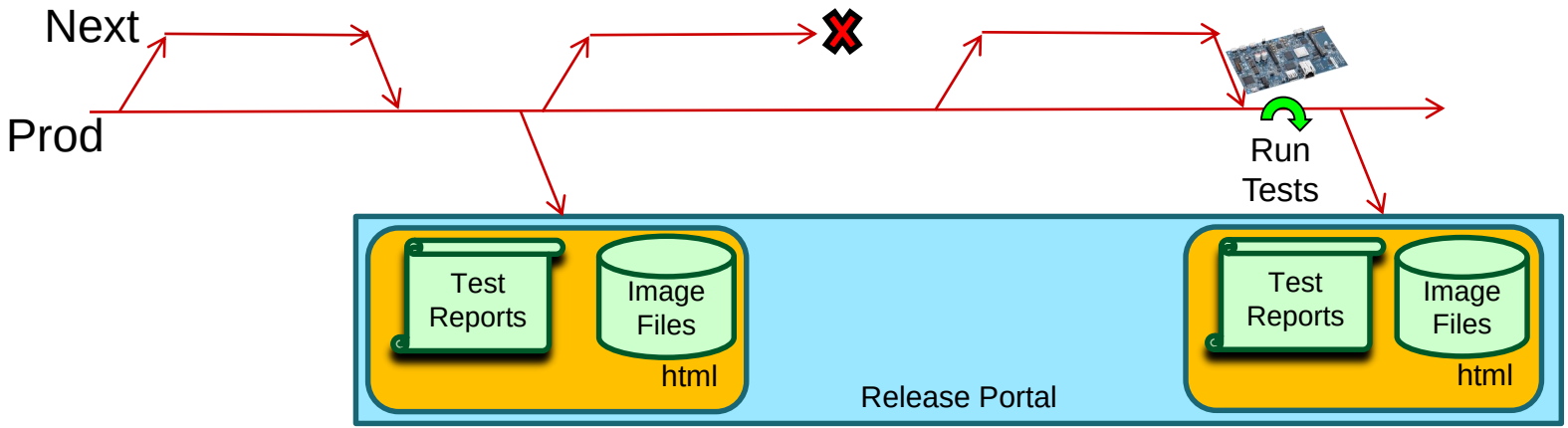
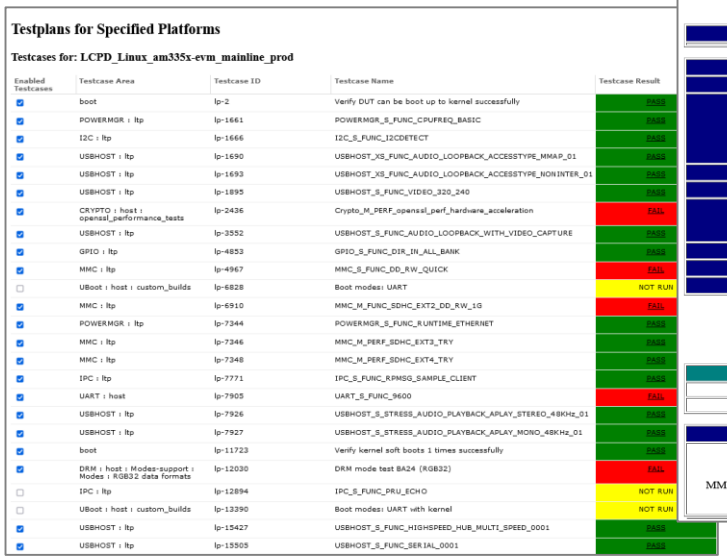


Upstream CI/CD

- Upstream CI/CD tests executed nightly
  - Expanded set of tests including device driver tests
  - Trade-off coverage and test execution time



Testplans for Specified Platforms

Testcases for: LCPD_Linux_am335x-evm_mainline_prod

Enabled Testcases	Testcase Area	Testcase ID	Testcase Name	Testcase Result
☑	boot	lp-2	Verify DUT can be boot up to kernel successfully	PASS
☑	POWERMGR : ltp	lp-1661	POWERMGR_S_FUNC_CPUFREQ_BASIC	PASS
☑	I2C : ltp	lp-1666	I2C_S_FUNC_I2CDETECT	PASS
☑	USBHOST : ltp	lp-1690	USBHOST_XS_FUNC_AUDIO_LOOPBACK_ACCESSTYPE_MMAP_01	PASS
☑	USBHOST : ltp	lp-1693	USBHOST_XS_FUNC_AUDIO_LOOPBACK_ACCESSTYPE_NONINTER_01	PASS
☑	USBHOST : ltp	lp-1895	USBHOST_S_FUNC_VIDEO_320_240	PASS
☑	CRYPTO : host : openssl_performance_tests	lp-2436	Crypto_M_PERF_openssl_perf_hardware_acceleration	FAIL
☑	USBHOST : ltp	lp-3552	USBHOST_S_FUNC_AUDIO_LOOPBACK_WITH_VIDEO_CAPTURE	PASS
☑	GPIO : ltp	lp-4853	GPIO_S_FUNC_DIR_IN_ALL_BANK	PASS
☑	MMC : ltp	lp-4967	MMC_S_FUNC_DD_RW_QUICK	FAIL
☐	UBoot : host : custom_builds	lp-6828	Boot modes: UART	NOT RUN
☑	MMC : ltp	lp-6910	MMC_M_FUNC_SDHC_EXT2_DD_RW_1G	FAIL
☑	POWERMGR : ltp	lp-7344	POWERMGR_S_FUNC_RUNTIME_ETHERNET	PASS
☑	MMC : ltp	lp-7346	MMC_M_PERF_SDHC_EXT3_TRY	PASS
☑	MMC : ltp	lp-7348	MMC_M_PERF_SDHC_EXT4_TRY	PASS
☑	IPC : ltp	lp-7771	IPC_S_FUNC_RPMSG_SAMPLE_CLIENT	PASS
☑	UART : host	lp-7905	UART_S_FUNC_9600	FAIL
☑	USBHOST : ltp	lp-7926	USBHOST_S_STRESS_AUDIO_PLAYBACK_APLAY_STEREO_48KHz_01	PASS
☑	USBHOST : ltp	lp-7927	USBHOST_S_STRESS_AUDIO_PLAYBACK_APLAY_MONO_48KHz_01	PASS
☑	boot	lp-11723	Verify kernel soft boots 1 times successfully	PASS
☑	DRM : host : Modes-support : Modes : RGB32 data formats	lp-12030	DRM mode test BA24 (RGB32)	FAIL
☐	IPC : ltp	lp-12894	IPC_S_FUNC_PRU_ECHO	NOT RUN
☐	UBoot : host : custom_builds	lp-13390	Boot modes: UART with kernel	NOT RUN
☑	USBHOST : ltp	lp-15427	USBHOST_S_FUNC_HIGHSPEED_HUB_MULTI_SPEED_0001	PASS
☑	USBHOST : ltp	lp-15505	USBHOST_S_FUNC_SERIAL_0001	PASS

Texas Instruments Test R

Target	
Tester	eptf108
Build	upstream.202404022059.prod_master_prod_914b18825f
Build Info	dtb=http://lcpd.itg.ti.com/builds/poky-master/prod/am335 evm.dtb;kernel=http://lcpd.itg.ti.com/builds/poky-master/ /zImage;var_test_no_stats=0;var_boot_attempts=2;nfs=ht evm/upstream.202404022059.prod/images/core-image-m //https://bitbucket.itg.ti.com/scm/vatf/vatf-scripts.git;var_
Test Case	4967
Test Script	LSP/TARGET/dev_test2.rb
Test Description	MMC_S_FUNC_DD_RW_QUICK MMC device w/r test with whatever fs in card MMC read write test with whatever fs in card \n The devi
Test Started	04/02/2024 10:07PM
Test Completed	04/02/2024 10:09PM
Report Generated	04/02/2024 10:09PM

Session Summary

Test Iterations Summary

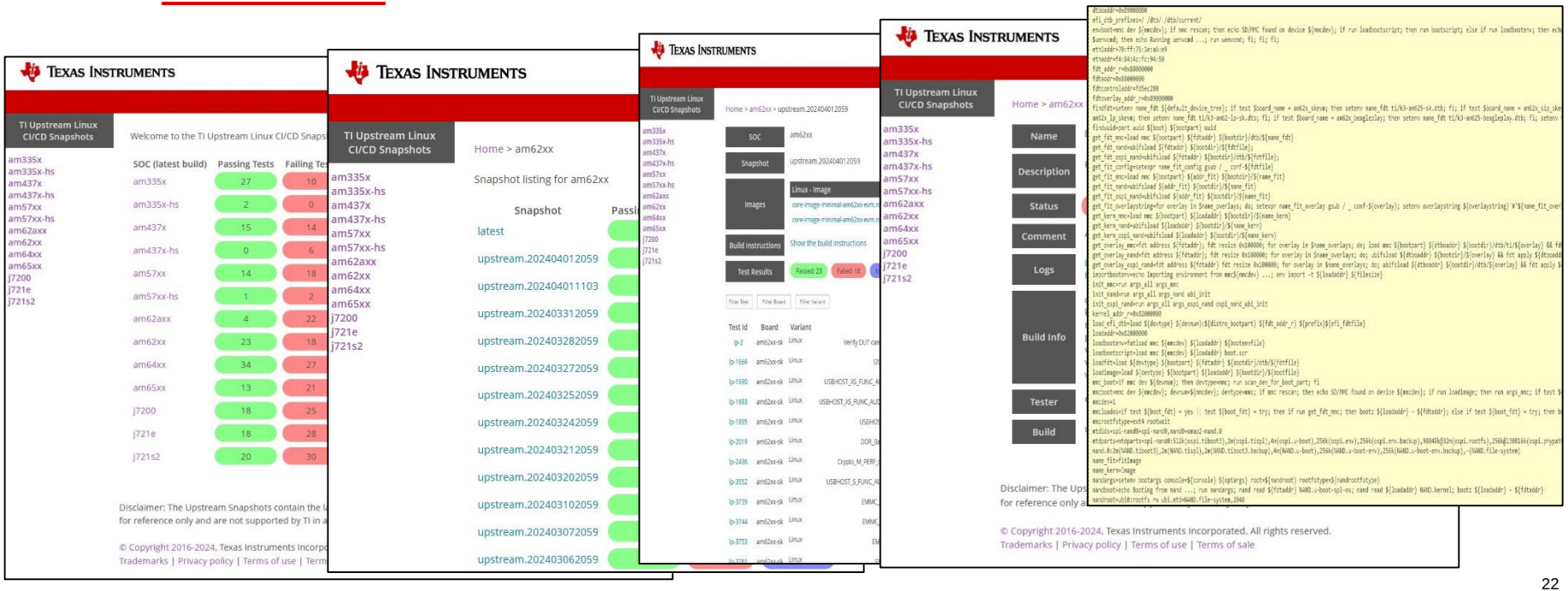
Equipment Logs
dut1
server1

Test	Result	
MMC_S_FUNC_DD_RW_QUICK MMC device w/r test with whatever fs in card MMC read write test with whatever fs in card \n The device node is specified in get_blk_device_node.sh	FAILED	|ERROR|Line: File: |ERROR|Line: File: |ERROR|Line: File:bl

```
[    0.094072] Setting up static identity map for 0x80300000 - 0x803000ac
[    0.097002] rcu: Hierarchical SRCU implementation.
[    0.097026] rcu:     Max phase no-delay instances is 1000.
[    0.103226] EFI services will not be available.
[    0.103592] smp: Bringing up secondary CPUs ...
[    0.103641] smp: Brought up 1 node, 1 CPU
[    0.103656] SMP: Total of 1 processors activated (996.14 BogoMIPS).
[    0.103669] CPU: All CPU(s) started in SVC mode.
[    0.104570] devtmpfs: initialized
[    0.120539] VFP support v0.3: implementor 41 architecture 3 part 30 variant c rev 3
[    0.120900] clocksource: jiffies: mask: 0xffffffff max_cycles: 0xffffffff, max_idle_ns: 19112604462750000
ns
[    0.120936] futex hash table entries: 256 (order: 2, 16384 bytes, linear)
[    0.126541] pinctrl core: initialized pinctrl subsystem
[    0.132153] DMI not present or invalid.
[    0.133851] NET: Registered PF_NETLINK/PF_ROUTE protocol family
[    0.136157] DMA: preallocated 256 KiB pool for atomic coherent allocations
[    0.140113] thermal_sys: Registered thermal governor 'step_wise'
[    0.140275] cpuidle: using governor menu
[    0.168372] platform panel: Fixed dependency cycle(s) with /ocp/interconnect@48000000/segment@300000
/target-module@e000/lcdc@0
[    0.169339] No ATAGs?
[    0.169361] hw-breakpoint: debug architecture 0x4 unsupported.
[    0.176120] Serial: AMBA PL011 UART driver
[    0.198046] iommu: Default domain type: Translated
[    0.198078] iommu: DMA domain TLB invalidation policy: strict mode
[    0.212550] SCSI subsystem initialized
[    0.213352] usbcore: registered new interface driver usbfs
[    0.213401] usbcore: registered new interface driver hub
[    0.213458] usbcore: registered new device driver usb
[    0.214692] pps_core: LinuxPPS API ver. 1 registered
[    0.214711] pps_core: Software ver. 5.3.6 - Copyright 2005-2007 Rodolfo Giometti <giometti@linux.it>
[    0.214736] PTP clock support registered
[    0.214950] EDAC MC: Ver: 3.0.0
[    0.221858] scmi_core: SCMI protocol bus registered
[    0.233460] vgaarb: loaded
[    0.234254] clocksource: Switched to clocksource dmtimer
[    0.260642] NET: Registered PF_INET protocol family
[    0.261050] IP idents hash table entries: 16384 (order: 5, 131072 bytes, linear)
[    0.262701] tcp_listen_portaddr_hash hash table entries: 512 (order: 0, 4096 bytes, linear)
[    0.262738] Table-perturb hash table entries: 65536 (order: 6, 262144 bytes, linear)
[    0.262755] TCP established hash table entries: 8192 (order: 3, 32768 bytes, linear)
[    0.262827] TCP bind hash table entries: 8192 (order: 5, 131072 bytes, linear)
[    0.263017] TCP: Hash tables configured (established 8192 bind 8192)
[    0.263178] UDP hash table entries: 512 (order: 2, 16384 bytes, linear)
[    0.263216] UDP-Lite hash table entries: 512 (order: 2, 16384 bytes, linear)
[    0.263395] NET: Registered PF_UNIX/PF_LOCAL protocol family
[    0.274705] RPC: Registered named UNIX socket transport module.
[    0.274732] RPC: Registered udp transport module.
[    0.274739] RPC: Registered tcp transport module.
[    0.274744] RPC: Registered tcp-with-tls transport module.
[    0.274750] RPC: Registered tcp NFSv4.1 backchannel transport module.
[    0.274773] PCI: CLS 0 bytes, default 64
[    0.276596] Initialise system trusted keyrings
[    0.277561] workingset: timestamp_bits=30 max_order=18 bucket_order=0
[    0.278057] squashfs: version 4.0 (2009/01/31) Phillip Lougher
```

Upstream Snapshots

- Customer facing Linux Upstream images and test results available on TI's software-dl website



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Upstream Testing

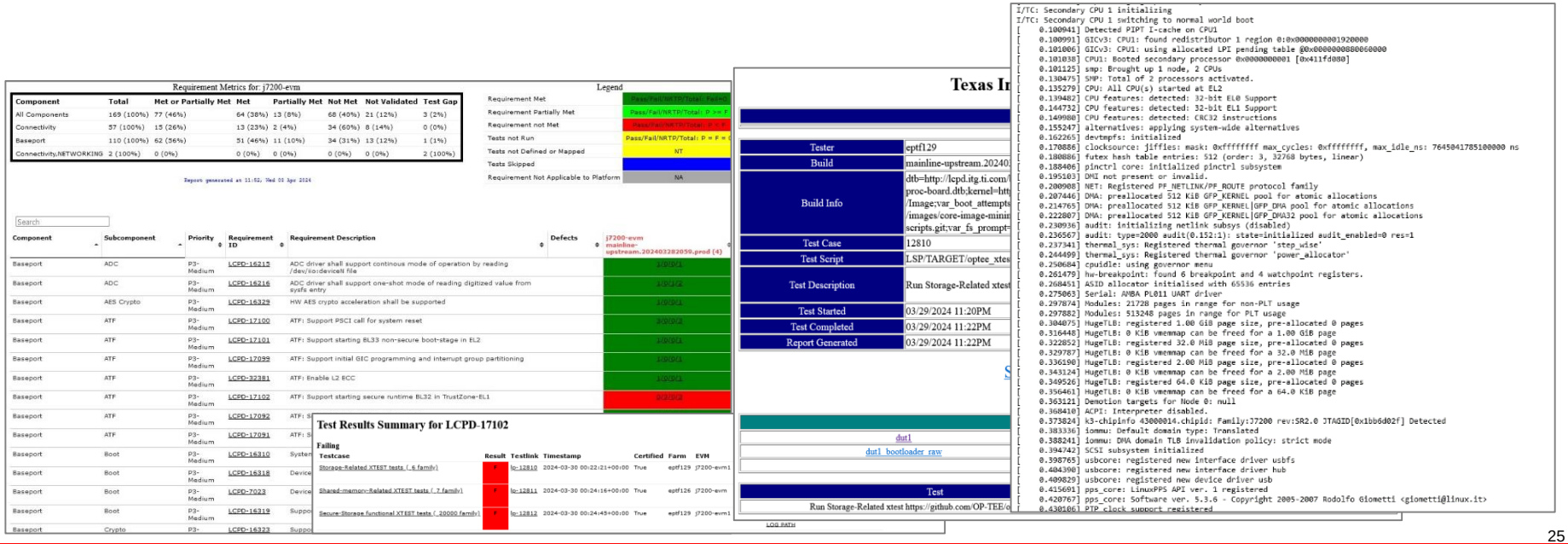
- KernelCI Testing
- Upstream CI/CD Testing
- **Full Upstream System Test**

Upstream System Test

- **Automatically** generated test plans based on requirements
  - 1000’s of testcases across all SoCs
  - Longer running tests including additional (external) driver tests
- **Automatically** flash SD cards with images to test
- **Automatically** collect and tabulate test results

Upstream System Test Automation - Reports

- **Automatically** generated test reports
- Not published to community today



Requirement Metrics for: j7200-evm

Component	Total	Met or Partially Met	Met	Partially Met	Not Met	Not Validated	Test Gap
All Components	169 (100%)	77 (46%)	64 (38%)	13 (8%)	68 (40%)	21 (12%)	3 (2%)
Connectivity	57 (100%)	15 (26%)	13 (23%)	2 (4%)	34 (60%)	8 (14%)	0 (0%)
Baseport	110 (100%)	62 (56%)	51 (46%)	11 (10%)	34 (31%)	13 (12%)	1 (1%)
Connectivity,NETWORKING	2 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (100%)

Report generated at 11:02, Wed 03 Apr 2024

Legend

Requirement Met	Pass/Fail/NRTP/Total: Fail=0
Requirement Partially Met	Pass/Fail/NRTP/Total: P >= F
Requirement not Met	Pass/Fail/NRTP/Total: P < F
Tests not Run	Pass/Fail/NRTP/Total: P = F = 0
Tests not Defined or Mapped	NT
Tests Skipped	
Requirement Not Applicable to Platform	NA

Search

Component	Subcomponent	Priority	Requirement ID	Requirement Description	Defects	j7200-evm mainline-upstream.20240322082059.prod (4)
Baseport	ADC	P3-Medium	LCPD-16215	ADC driver shall support continous mode of operation by reading /dev/iio:deviceX file		1/0/0/1
Baseport	ADC	P3-Medium	LCPD-16216	ADC driver shall support one-shot mode of reading digitized value from sysfs entry		1/0/0/1
Baseport	AES Crypto	P3-Medium	LCPD-16329	HW AES crypto acceleration shall be supported		1/0/0/1
Baseport	ATF	P3-Medium	LCPD-17100	ATF: Support PSCI call for system reset		2/0/0/2
Baseport	ATF	P3-Medium	LCPD-17101	ATF: Support starting BL33 non-secure boot-stage in EL2		1/0/0/1
Baseport	ATF	P3-Medium	LCPD-17099	ATF: Support initial GIC programming and interrupt group partitioning		1/0/0/1
Baseport	ATF	P3-Medium	LCPD-32381	ATF: Enable L2 ECC		1/0/0/1
Baseport	ATF	P3-Medium	LCPD-17102	ATF: Support starting secure runtime BL32 in TrustZone-EL1		0/2/0/2
Baseport	ATF	P3-Medium	LCPD-17092	ATF: S		
Baseport	ATF	P3-Medium	LCPD-17091	ATF: S		
Baseport	Boot	P3-Medium	LCPD-16310	Systen		
Baseport	Boot	P3-Medium	LCPD-16318	Device		
Baseport	Boot	P3-Medium	LCPD-7023	Device		
Baseport	Boot	P3-Medium	LCPD-16319	Suppo		
Baseport	Crypto	P3-	LCPD-16323	Suppo		

Test Results Summary for LCPD-17102

Failing

Testcase	Result	Testlink	Timestamp	Certified	Farm	EVM
Storage-Related XTEST tests (_6 family)	F	lc-12810	2024-03-30 00:22:21+00:00	True	eptf129	j7200-evm1
Shared-memory-Related XTEST tests (_7 family)	F	lc-12811	2024-03-30 00:24:16+00:00	True	eptf126	j7200-evm
Secure-Storage functional XTEST tests (_20000 family)	F	lc-12812	2024-03-30 00:24:45+00:00	True	eptf129	j7200-evm1

Texas In

Tester	eptf129
Build	mainline-upstream.20240
Build Info	dtb=http://lcpd.itg.ti.com/ proc-board.dtb;kernel=htt /Image;var_boot_attempts /images/core-image-minir scripts.git;var_fs_prompt=
Test Case	12810
Test Script	LSP/TARGET/optee_xtes
Test Description	Run Storage-Related xtest
Test Started	03/29/2024 11:20PM
Test Completed	03/29/2024 11:22PM
Report Generated	03/29/2024 11:22PM

dut1

dut1_bootloader_raw

Test

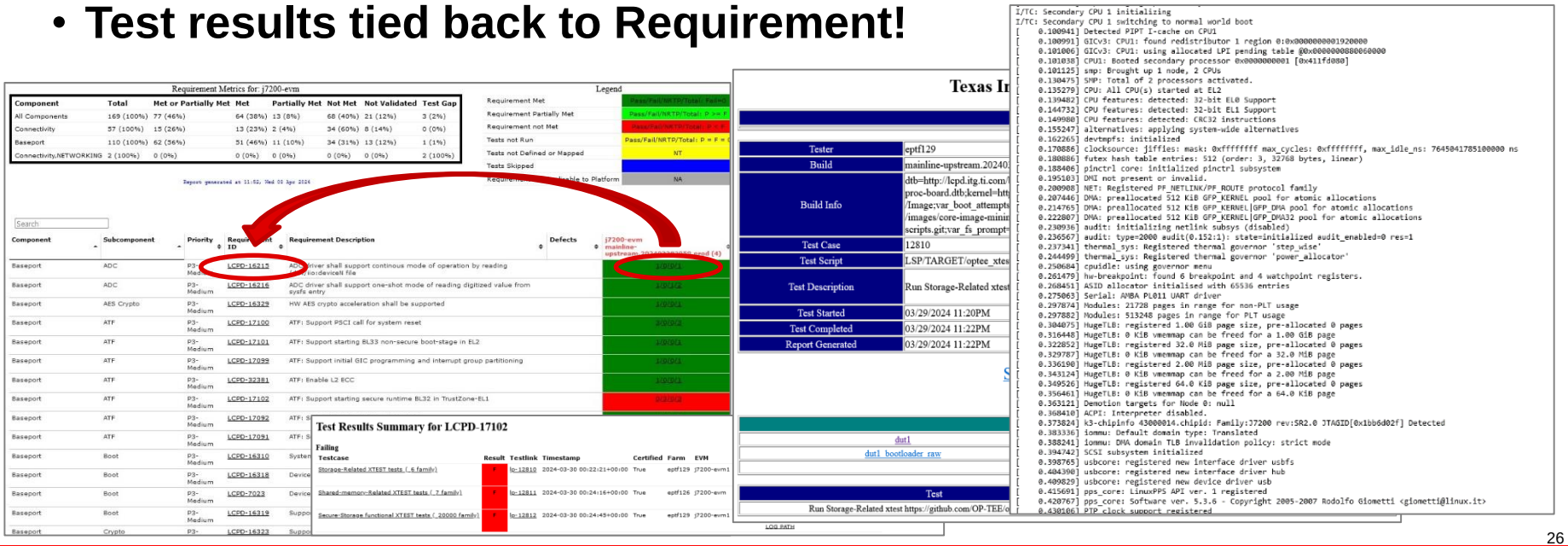
Run Storage-Related xtest https://github.com/OP-TEE/o

LOG PATH

```
I/TC: Secondary CPU 1 initializing
I/TC: Secondary CPU 1 switching to normal world boot
[    0.100941] Detected PIPT I-cache on CPU1
[    0.100991] GICv3: CPU1: found redistributor 1 region 0:0x0000000001920000
[    0.101006] GICv3: CPU1: using allocated LPI pending table @0x0000000880060000
[    0.101038] CPU1: Booted secondary processor 0x0000000001 [0x411fd080]
[    0.101125] smp: Brought up 1 node, 2 CPUs
[    0.130475] SMP: Total of 2 processors activated.
[    0.135279] CPU: All CPU(s) started at EL2
[    0.139482] CPU features: detected: 32-bit EL0 Support
[    0.144732] CPU features: detected: 32-bit EL1 Support
[    0.149080] CPU features: detected: CRC32 instructions
[    0.155247] alternatives: applying system-wide alternatives
[    0.162265] devtmpfs: initialized
[    0.170886] clocksource: jiffies: mask: 0xffffffff max_cycles: 0xffffffff, max_idle_ns: 7645041785100000 ns
[    0.180886] futex hash table entries: 512 (order: 3, 32768 bytes, linear)
[    0.188406] pinctrl core: initialized pinctrl subsystem
[    0.195103] DMI not present or invalid.
[    0.200908] NET: Registered PF_NETLINK/PF_ROUTE protocol family
[    0.207446] DMA: preallocated 512 KiB GFP_KERNEL pool for atomic allocations
[    0.214765] DMA: preallocated 512 KiB GFP_KERNEL|GFP_DMA pool for atomic allocations
[    0.222807] DMA: preallocated 512 KiB GFP_KERNEL|GFP_DMA32 pool for atomic allocations
[    0.230936] audit: initializing netlink subsys (disabled)
[    0.236567] audit: type=2000 audit(0.152:1): state=initialized audit_enabled=0 res=1
[    0.237341] thermal_sys: Registered thermal governor 'step_wise'
[    0.244499] thermal_sys: Registered thermal governor 'power_allocator'
[    0.250684] cpuidle: using governor menu
[    0.261479] hw-breakpoint: found 6 breakpoint and 4 watchpoint registers.
[    0.268451] ASID allocator initialised with 65536 entries
[    0.275063] Serial: AMBA PL011 UART driver
[    0.297874] Modules: 21728 pages in range for non-PLT usage
[    0.297882] Modules: 513248 pages in range for PLT usage
[    0.304075] HugeTLB: registered 1.00 GiB page size, pre-allocated 0 pages
[    0.316448] HugeTLB: 0 KiB vmemmap can be freed for a 1.00 GiB page
[    0.322852] HugeTLB: registered 32.0 MiB page size, pre-allocated 0 pages
[    0.329787] HugeTLB: 0 KiB vmemmap can be freed for a 32.0 MiB page
[    0.336190] HugeTLB: registered 2.00 MiB page size, pre-allocated 0 pages
[    0.343124] HugeTLB: 0 KiB vmemmap can be freed for a 2.00 MiB page
[    0.349526] HugeTLB: registered 64.0 KiB page size, pre-allocated 0 pages
[    0.356461] HugeTLB: 0 KiB vmemmap can be freed for a 64.0 KiB page
[    0.363121] Demotion targets for Node 0: null
[    0.368410] ACPI: Interpreter disabled.
[    0.373824] k3-chipinfo 43000014.chipid: Family:J7200 rev:SR2.0 JTAGID[0x1bb6d02f] Detected
[    0.383336] iommu: Default domain type: Translated
[    0.388241] iommu: DMA domain TLB invalidation policy: strict mode
[    0.394742] SCSI subsystem initialized
[    0.398765] usbcore: registered new interface driver usbfs
[    0.404390] usbcore: registered new interface driver hub
[    0.409829] usbcore: registered new device driver usb
[    0.415691] pps_core: LinuxPPS API ver. 1 registered
[    0.420767] pps_core: Software ver. 5.3.6 - Copyright 2005-2007 Rodolfo Giometti <giometti@linux.it>
[    0.430186] PTP clock support registered
```

Upstream System Test Automation - Reports

- **Automatically** generated test reports
- Not published to community today
- **Test results tied back to Requirement!**



Towards Community Based Testing…

Towards Community Based Testing…

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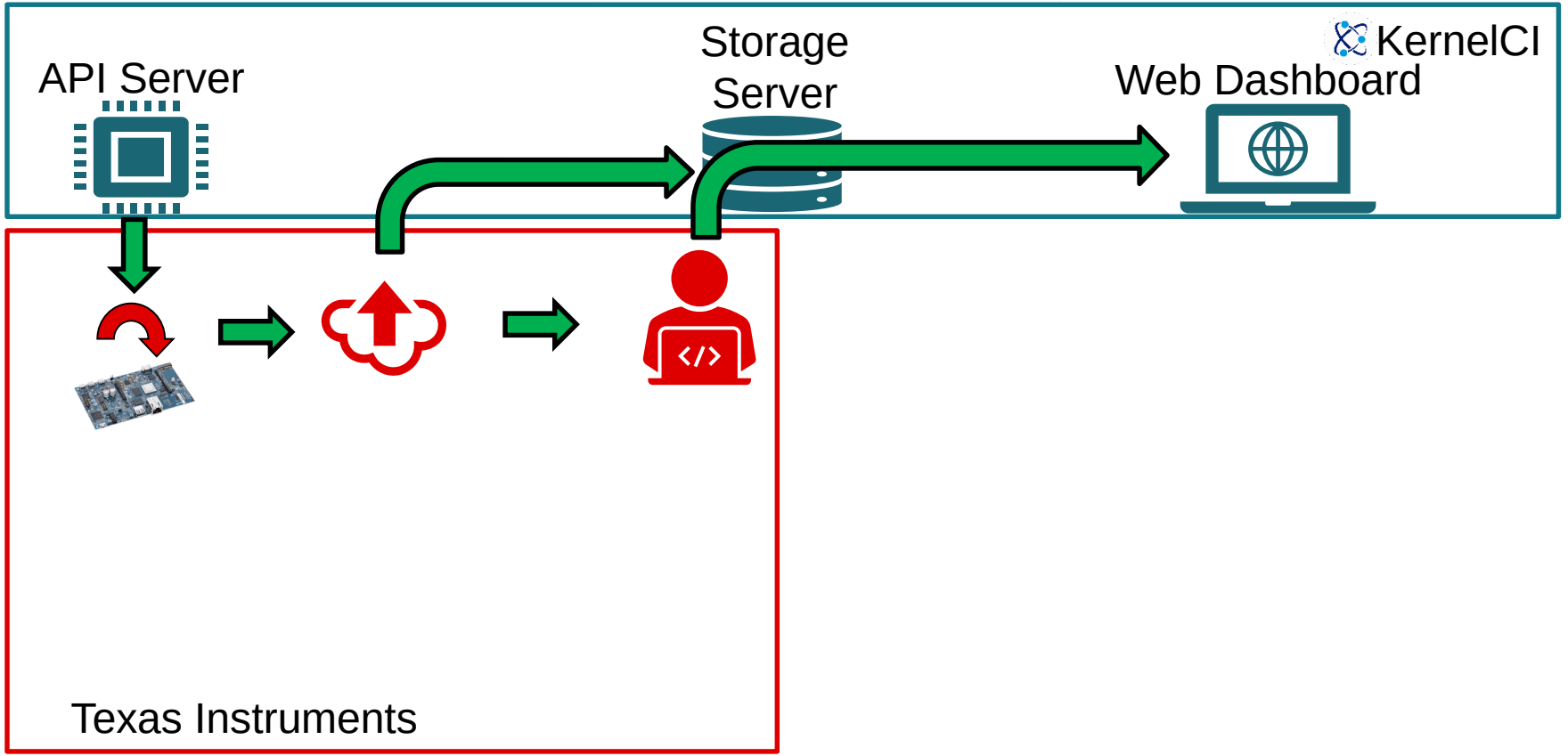

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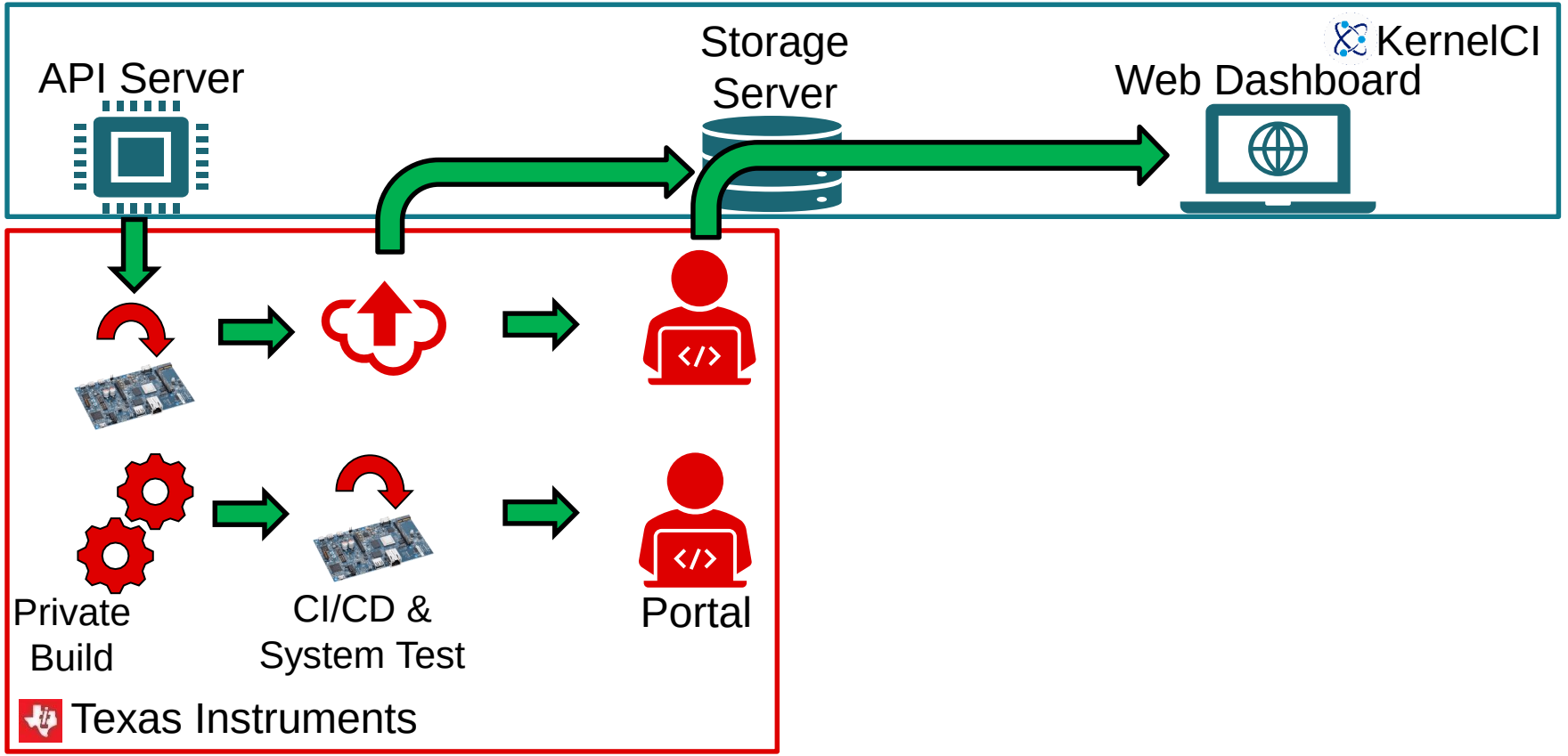

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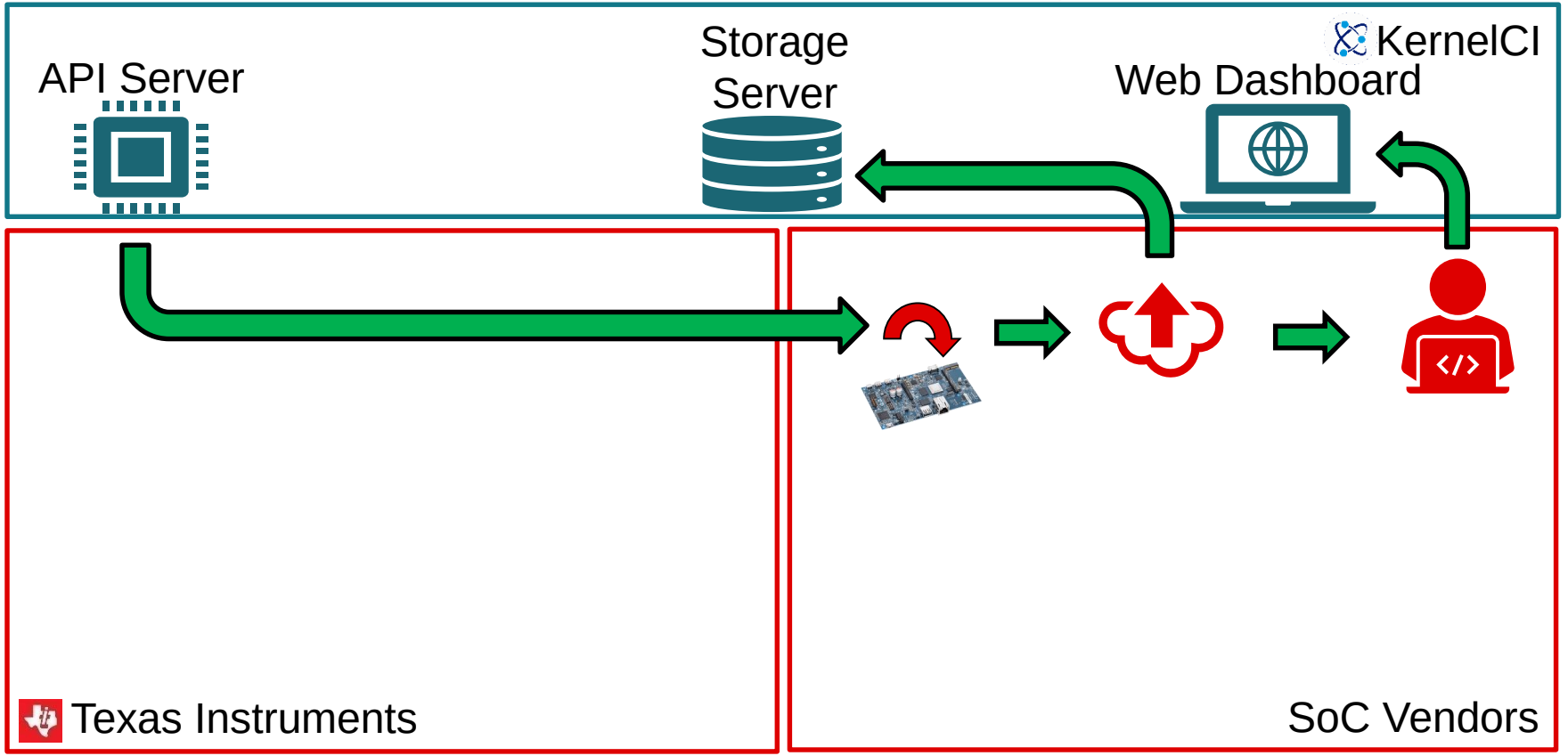

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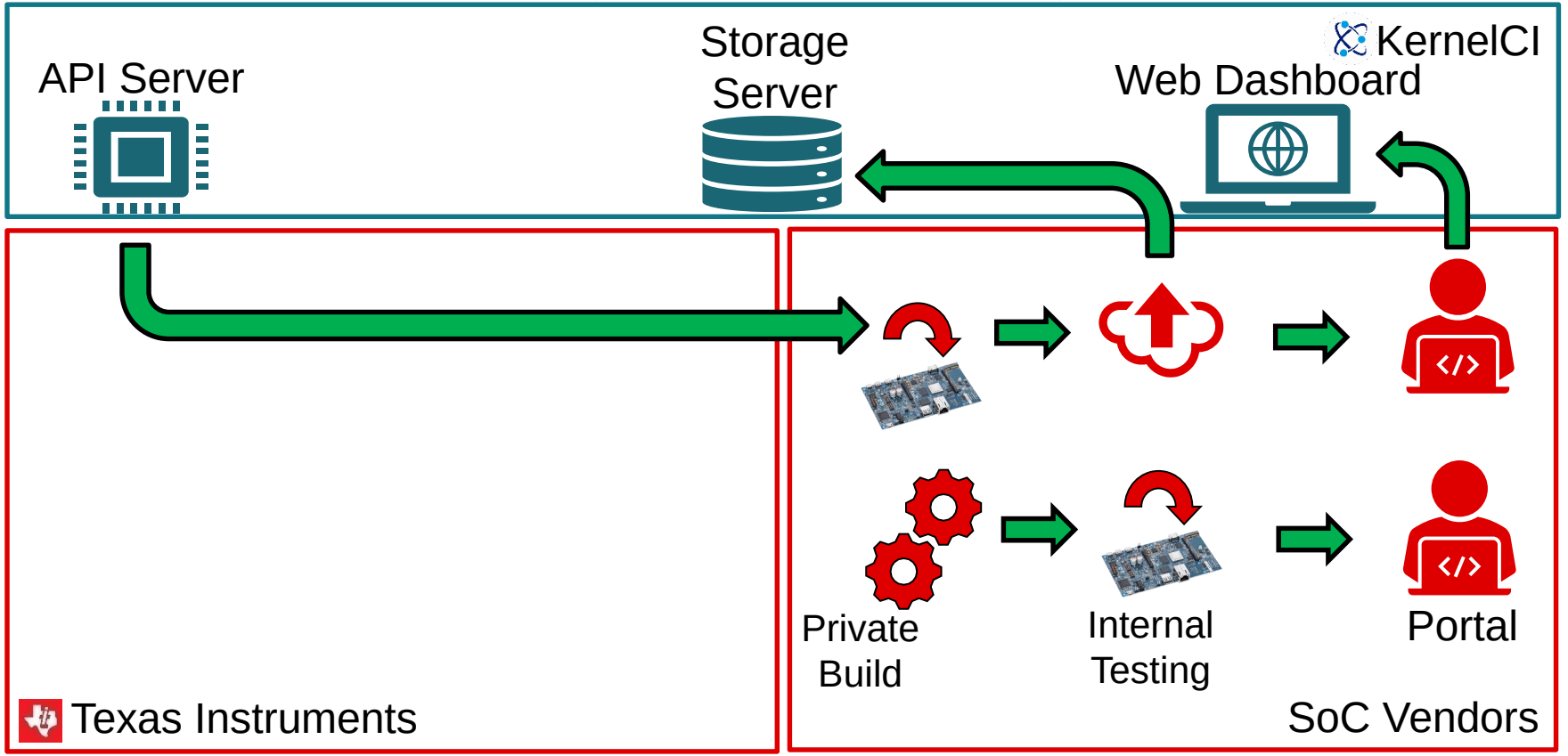

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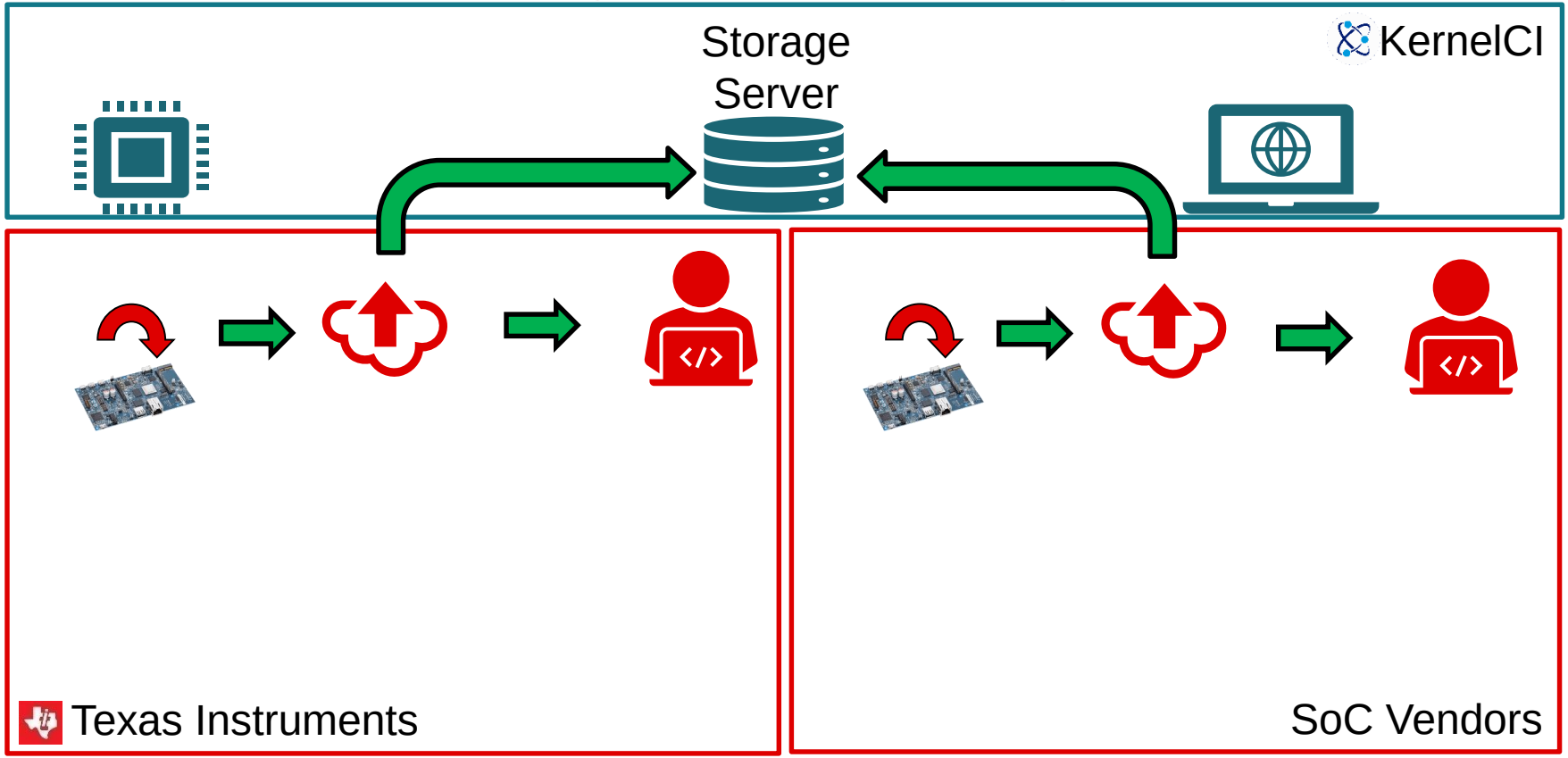


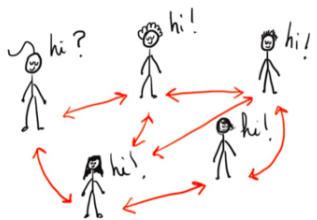
Towards Community Based Testing…

- Objective:
  - Product quality, Reliable Mainline Software
- Challenge: TRUST!
- Solution: Transparency
  - Standardizing
  - Decentralizing
  - Trusted Reporting

Solution: Standardized Testing

- Testing today's complex embedded systems are multifaceted
  - Multi-OS and heterogenous ecosystems
  - Linux testing vs. Traditional JTAG based RTOS testing
- Few Areas of improvement:
  - Test Farm Control & deployment – Lava, Labgrid,… (collaborate for the best of both worlds)
  - Host side test frameworks – pytest?
  - DuT frameworks – LTP-DDT?
  - Protocol standardized testing – example: TSN/Industrial protocol
  - Test Harness hardware - examples:
    - Camera Test harness
    - PCIe Test harness
    - Board Test interface harness
  - Testing should scale Distributions
- Focus is reproducibility

With no shared institutions (such as language or legal standards), connections are hard to form.



When everyone adopts the same institution, connections can multiply in the network.

Network and Languages CC-SA 4.0

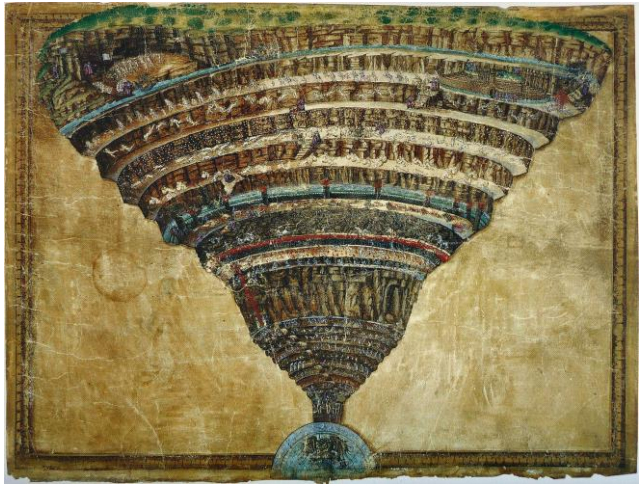
Solution: Decentralizing

OrionCC CC-SA 3.0

- Solution:
  - Test scale over time
  - Changing business priorities
  - Geographical locations
- Testing time is $$$ - more tests are needed for better quality, but more tests more time. Decentralizing testing provides better coverage
- No business retains a single priority over time. Decentralizing removes pressures on a single point of failure.
- No single physical location can infinitely scale – new platforms, new technologies keep appearing. Older platforms are still in production use – dropping them should NOT be an option!
- KernelCI model of decentralized testing is ideal if we can scale across Operating Systems (Linux, Zephyr...), Platforms (Server, embedded MPUs, MCUs..)

Solution: Reporting

- Fear of reporting bad results must be overcome for transparency
- Solution:
  - Providing decentralized data retrieval allows richer decentralized reporting options.
  - Towards community defined "badge" for reporting quality?
    - Data source
    - Quality of report without bias (standard report templates?)
- KernelCI today addresses an open reporting scheme, but data sources are still API driven.



Map of Hell public domain in the United States

Conclusion

- KernelCI common location for publishing and gauging kernel quality
- Scaling up to additional CI/CD, System Testing provides additional confidence and visibility of quality

- Call for Action for us as an Open Source Community:
  - **Common** Testing framework beyond Linux kernel would leverage shared solution across vendors
  - **KernelCI** could be an umbrella for facilitating standardized Open Source ecosystem testing for production worthy products using mainline/upstream s/w itself

Credits and Acknowledgement

Thank you!

- Texas Instruments Inc.
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- Pengutronix

Q&A

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